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Competition and price asymmetries in the Greek oil sector: an empirical analysis on gasoline market

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Abstract This article attempts to investigate the issue of asymmetries in the transmission of shocks to input prices and exchange rate onto the wholesale and retail price of gasoline respectively. For this purpose, we utilise the error-correction methodology in the Greek gasoline market. The sample consists of monthly data covering the period of January 1988 to June 2006. We also try to analyse by using impulse response functions the effect of competition on the dynamic adjustment of gasoline price to which has been paid scant attention in the past. The results favour the common perception that retail gasoline prices respond asymmetrically to cost increases and decreases both in the long and the short-run. At the wholesale segment, there is a symmetric response of the spot prices of gasoline towards the adjustment to the short-run responses of the exchange rate. Lastly, after the deregulation, wholesale prices of gasoline tend to gradually restore equilibrium triggered by a price shock compared to the regulated period.

Keywords Asymmetries · Gasoline market · Impulse response functions · Competition · Deregulation

JEL Classification D40 · L11 · C51 · C22

1 Introduction and survey of the literature

This article has two objectives. Firstly, we explore whether asymmetric pricing can be identified in the Greek gasoline market by utilising error correction methodology on

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the monthly price changes. Despite its crucial importance due to the recent oil price hikes, this analysis has not yet been done for Greece. Secondly, we try to analyze the level of competition in the oil market in Greece to which has been paid rather scant attention by the earlier studies. This kind of analysis tries to make the contribution in this article more significant and novel. Besides, an understanding of the Greek experience will be useful for countries that pursue strategies of sectoral deregulation especially in the strategic sectors of their economy such as electricity, natural gas, water, and telecommunications.

Within the last years there is a substantial body of literature investigating the existence of price asymmetry in the gasoline market. In these studies, there is a wide diversification concerning one or more of the following aspects: the country under examination, the time frequency of the period of the data used, the stage of the transmission mechanism (retail or wholesale) and the econometric model employed in the empirical investigation. For a good survey of asymmetric adjustment literature, see Frey and Manera (2007). Table 1 reports the main empirical papers.

The majority of these studies apply cointegration techniques and especially Engle–Granger methodology by utilising an asymmetric error-correction model in order to discover the existence of price asymmetries. More specifically, Kirchgässner and Kübler (1992), used an error correction model to investigate possible price asymmetries in the wholesale and retail gasoline and heating oil markets in Germany for the period 1972–1989. Their results differ according to the relevant time period. More specifically, for the 1980s, the authors find rapid symmetric and full adjustment of the retail prices to the spot prices (Rotterdam prices), whereas there is considerable short-run asymmetry in the 1970s.

A different approach is followed in the pioneering study of Bacon (1991) who uses a quadratic quantity adjustment function to estimate the existence of price asymmetries in wholesale and retail gasoline market in the United Kingdom respectively. In this study, bi-weekly data are used for the period 1982–1989. According to the main findings, the upward adjustment process is slightly faster than price reductions and the period of adjustment more concentrated than was the case when costs fell. Moreover, changes in the exchange rate necessitate 2 extra weeks relative to product prices before being incorporated in the retail gasoline prices.

Most of the studies under scrutiny primarily focus on prices asymmetries and few of them allow for other asymmetries. The paper by Galeotti et al. (2003) re-examines the issue of asymmetries in the retail market of gasoline by allowing possibly asymmetric role of the exchange rate. In their stimulating paper the issue of asymmetric pricing on specific European countries (Germany, France, UK, Italy, Spain) is examined by using an error-correction model and bootstrapping techniques in order to overcome the low-power problem of conventional testing procedures. In contrast to several previous findings, the results generally point to widespread differences in both adjustment speeds and short-run responses on prices and exchange rate when input prices are volatile.

In order to assess the issue of asymmetric gasoline pricing, a small number of studies use daily data (Asplund et al. 2000; Bachmeier and Griffin (2003); Johnson 2002) for a number of countries (Sweden, United Kingdom and United States).

Table 1 Summary of literature review

Study	Country/product	Frequency/period	Stage of transmission	Model	Price asymmetry	Other asymmetries
Asplund et al. (2000)	Sweden/gasoline	Daily/1980–1996	Retail market	Error-correction model	Only in the short-run period	No
Bachmeier and Griffin (2003)	United States/gasoline	Daily/1985–1998	Wholesale market	Error-correction model	No	No
Bacon (1991)	United Kingdom/gasoline	Bi weekly/1982–1989	Wholesale and retail market	Quadratic quantity adjustment function	Yes	Yes
Balke et al. (1998)	United States/gasoline	Weekly/1987–1997	Wholesale and retail market	Distributed lag model Error correction model	Persistent when using the error-correction model	No
Bettendorf et al. (2003)	Netherlands/gasoline	Weekly/1996–2001	Retail market	Error-correction model	Asymmetric pricing differs over the datasets	No
Borenstein et al. (1997)	United States/gasoline	Weekly/1986–1992	Wholesale and retail market	Error-correction model	Yes	No
Contin et al. (2006)	Spain/gasoline	Weekly/1993–2004	Retail market	Error-correction model	No	No

Table 1 continued

Study	Country/product	Frequency/period	Stage of transmission	Model	Price asymmetry	Other asymmetries
Duffy-Deno (1996)	Salt Lake City (US)/gasoline	Weekly/1989–1993	Wholesale and retail market	Error-correction model	Yes	No
Galeotti et al. (2003)	Germany, France, UK, Italy and Spain/gasoline	Monthly/1985–2000	Wholesale and retail market	Error-correction model	Yes	Exchange rate
Godby et al. (2000)	Canada/gasoline	Weekly/1990–1996	Retail market	Threshold autoregressive model	No evidence	No
Johnson (2002)	United States/gasoline and diesel	Weekly/1996–1998	Retail market	Error-correction model	Yes	No
Kaufmann and Laskowski (2005)	United States/gasoline and home heating oil	Monthly/1986–2002	Wholesale and retail market	Error-correction model	Only for heating oil	No
Kirchgässner and Kübler (1992)	West Germany/gasoline and light heating oil	Monthly/1972–1989	Wholesale and retail market	Error-correction model	Only during 1970s	No
Manning (1991)	United Kingdom/gasoline	Monthly/1973–1988	Retail market	Error-correction model	No evidence	No
Reilly and Witt (1998)	United Kingdom/gasoline	Monthly/1982–1995	Retail market	Error-correction model	Yes	Exchange rate
Shin (1994)	United States/gasoline	Monthly/1982–1990	Wholesale market	Error-correction model	No	No

The remainder of the article is organized as follows. In Sect. 2 a detailed overview of the oil market in Greece is provided, together with a presentation of the level of competition in the three relevant markets (refining wholesale and retail market). Section 3 offers a detailed description of the empirical model and the data used, while Sect. 4 reports our estimation results. Finally, Sect. 5 encapsulates the main results of this article presented together with some policy implications.

2 The oil sector in Greece

2.1 Market description

In contrast to many European countries (Germany, France, United Kingdom, etc) oil sector in Greece is oriented into three distinct relevant markets (refining wholesale and retail market).

In the refining market, there are only two companies (Hellenic Petroleum S.A. and Motor Oil Hellas S.A.) that cover the 90% of the oil demand in Greece while the rest is imported from the wholesale companies (Fig. 1). Refiners may sell gasoline and other petroleum products (diesel, heating oil) directly to "large final consumers" such as trucking firms, industrial manufacturers and utilities or to independent retailers (non-branded petrol stations). However, the majority of refiner's gasoline sales are made to oil companies (wholesalers).

In the Greek wholesale segment, oil companies are legally separated from refining operations and are allowed to import and export oil products and sell them to filling station operators. According to the provisions of the oil law (3054/2002), all

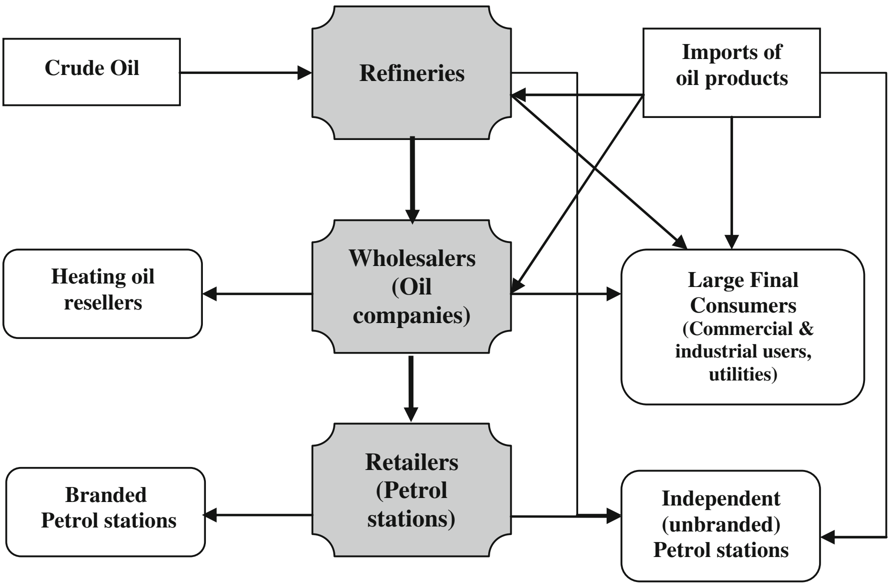

Fig. 1 Structure of Greek oil sector in Greece

Table 2 Market shares (%) in petroleum products, CR-4, and HHI in Greece (2000–2005)

Company	2000	2001	2002	2003	2004	2005	Mean annual average rate
EKO	18.02	19.25	18.75	19.01	17.60	17.30	−0.8
BP	21.09	19.80	18.76	18.55	18.50	17.10	−4.1
SHELL	12.01	15.44	15.52	15.91	15.50	15.50	5.2
AVINOIL	8.07	9.76	9.46	9.24	8.60	8.50	1.0
JETOIL	7.18	7.29	8.17	7.20	7.50	7.60	1.1
AIGAION OIL	1.52	2.88	3.48	3.94	5.00	6.00	31.6
ELINOIL	4.42	4.65	5.05	5.16	4.70	5.00	2.5
REVOIL	2.45	3.00	3.13	3.38	3.80	4.20	11.4
SILK OIL	2.73	2.99	3.05	3.21	3.40	3.50	5.1
ETEKA	2.01	2.18	2.39	2.64	3.10	3.40	11.1
DRACOIL	2.38	2.48	2.53	2.71	2.60	2.40	0.2
CYCLON	1.29	1.54	1.59	1.57	1.70	1.90	8.1
OTHERS	16.83	8.74	8.12	7.48	8.00	7.60	−14.7
Total	100.00	100.00	100.00	100.00	100.00	100.00	–
CR-4	59.19	64.25	62.49	62.71	60.20	58.40	–
HHI	1132	1226	1185	1189	112	1086	–

The ranking of the market shares concerns the year 2005
Source: Bikos (2004) for the period 2000–2003 and Industry and Energy Magazine, May 2006 for the years 2004–2005

companies (oil companies and large final consumers such as electricity and aviation companies) are allowed to import oil products directly provided that they can meet the 90-day stockholding obligations. In terms of market power, EKO followed by BP and SHELL (Table 2) are the three market leaders with a totally market share of 50% (2005). The next largest player is AVINOIL (8.5%), followed by JETOIL (7.6%), AIGAION OIL (6.0%) and ELINOIL (5.0%), while the rest holds ∼23% of the wholesale segment. Each company sells its products (gasoline, diesel and heating oil) through branded filling stations.

In Greece, there is a relatively large number of petrol filling stations compared to the population. It is estimated that seven filling stations correspond to ten thousand residents, while in Germany for example the proportion is only two stations per ten thousand habitants. More specifically, there are ∼8.500 petrol filling station operators (nearly 600 are unbranded) that cover the increasing demand for oil products. The majority of them are company owned dealer operated (CODO) or dealer owned dealer operated (DODO).The majority of petrol stations is situated close to the Attica region and represents half of the total turnover of the retail market. Apart from filling station operators, there is a small number of traders (so called "resellers") that usually sell directly to the final consumers heating oil and kerosene.

To sum up, several different entities are involved in the pricing of gasoline (and other petroleum products) at the downstream level. When gasoline is sold from the refinery to the oil company, the price for this transaction is called the producer price or ex-refinery price. The price charged for gasoline by the refiner or the oil company to the independent and branded petrol stations respectively is called the wholesale price. Finally, the price the petrol station charges the consumer is called the retail price.[1]

2.2 Competition intensity in the relevant markets

The Greek oil market was deregulated in 1992 and competition has evolved in all of the three segments. During the regulated period, the government retained the exclusive right to set the prices in all of the relevant market (refining wholesale and retail prices). In addition, the Greek government had the sole responsibility for the supply of crude oil and the provision of the domestic market with petroleum products. The government not only determined the logistic scheme of the oil companies (i.e. 70% of the domestic market was covered from the refineries of the Public Oil Corporation, later known as Hellenic Petroleum S.A. and the rest 30% from the other two private refineries) but totally controlled the ex-refinery price, the profit margins of the oil companies and the petrol station owners and the wholesale and retail price of the petroleum products. As a result, oil companies, were only active in the wholesale segment in contrast to other European countries that play significant role in all of the relevant markets of the oil industry (from refining to retailing).

However, with the law 2008/1992, oil market was deregulated and petroleum product prices have been set freely in all of the market segments. More specifically, Hellenic Petroleum S.A. announces daily the ex-refinery prices to the next level of oil industry (wholesalers) and the other private refineries (now only Motor Oil S.A.) charge similar prices providing volume discounts to their customers (oil companies, large final consumers). Each oil company is free to set its prices and the profit margins, while petrol station owners set their retail prices and the profit margins according to local competition and the level of their cost (fixed and variable cost). Although gasoline and oil prices have been set freely in the market since 1992, the government retains the right to set price ceiling if it considers that the market is not functioning well.[2]

Deregulation changed the level of "competition" in the Greek oil industry in several ways. Oil companies tried to differentiate their marketing strategy by giving emphasis on the quality and the specific ingredients of their products (gasoline, diesel oil, heating

[1] The differences between prices at various levels in the marketing chain are called "margins". Therefore, the difference between the retail and wholesale price is called the wholesale-retail margin. The difference between the wholesale price and producer price is called producer–wholesale margin and the overall difference is called producer–retail margin (Karrenbrock 1991).

[2] The Ministry of Development that monitors the oil market in Greece has used the above mechanism for specific prefectures (Thesprotia, Arta, Ioannina, Cyclades, etc) in 2003. However, the measure did not have the anticipated results (RAE 2004).

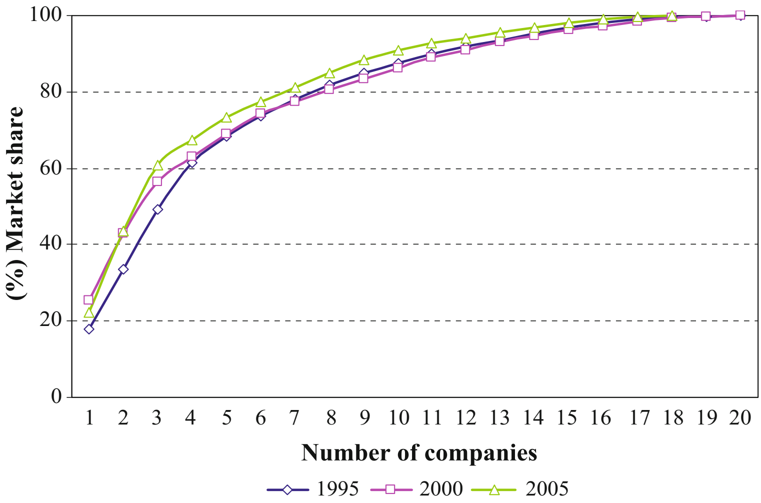

Fig. 2 Market concentration in the wholesale oil segment in Greece. *Source*: Author's estimations

oil, etc.) such as additives.[3] Their efforts focus on the establishment of a strong brand name and high level of customer loyalty. Their strategy relies upon the advertisement and the high quality service to their customers by offering gifts and other benefits. Therefore in order to raise the level of their sales, oil companies provide several benefits through their petrol stations network (i.e. car washing, dishes, toys, plates and glasses, music CD's, loyalty cards, etc). Usually the gift is connected to a minimum specified quantity of a fuel that customer must buy (Bikos 2004).

As a result, after the regulated period, competition in the oil industry and especially in the wholesale segment is not restricted only to the price level but has expanded in other market areas as well (advertisement, quality and brand names, appearance and good service of the petrol stations, benefits, gifts, etc).

Deregulation has also changed the level of market concentration in the wholesale and retail segment of the oil industry. As far as the wholesale market is concerned, it has to be mentioned that after 1992, the level of market concentration has been affected by the regulatory changes. The market share that claimed the four major oil companies in 1995 (CR-4 index) was estimated in 61.5%, while in 2005 the four leading companies possessed the 67.3% of the total sales of gasoline (Fig. 2). Also the first eight oil companies possessed the 81.9% of the market in 1995 (CR-8 index) while in 2005 claimed the 85.0% of the total sales of gasoline. It is interesting to highlight that within the last decade, the concentration of the market has shown a steady increase due to mergers and acquisitions. The Hirschman–Herfindahl index (HHI) has shown a slow decrease reaching the level of 1086 in 2005 compared to 1106 in 1995 (−1.8%).

[3] In order to distinguish the quality of their products and focus on the brand name, major oil companies like BP, SHELL and EKO sell their products by giving them different names such as "Ultimate", V-power" and "Kinitron", respectively.

In the retail segment, there is a steady increase in the number of petrol stations since the deregulation. This is mainly attributed to the relatively high profit margins of the retailers in contrast to other European countries.

Despite the existence of the deregulation in the oil industry, competition in the other segments of the market except for retailing is still limited. The following analysis will try to highlight the main distortions of competition in the three distinct relevant markets.

In the refining segment, apart from significant barriers to entry that favour the incumbent firms (i.e. sunk cost, economies of scope and scale, legal restrictions, etc) there are also potential problems hindering the level of competition. The major problem is connected to the existing strategic stockholding obligation system.[4] Due to specific restrictions (i.e. lack of storage, strict environmental legislation, bureaucracy, system of compulsory oil reserves in the Greek territory) a marketer (oil company, end-user) cannot easily import oil products.

The low magnitude of oil imports is accelerated from the absence of third-party access regulation, since if a marketer wants to import oil products must rent space from refineries in order to comply with the 90-day obligation following a commercial agreement and paying a negotiated third-party access tariff. As a result, and due to the above-mentioned reasons, imports in Greece are still limited.

In the wholesale market, entry is not restrained by significant technical, legal or economic barriers to entry. Provided that a company has the relevant magnitude and the necessary level of infrastructure (i.e. investment capital, collaboration with oil suppliers, distribution network, and stockholding capacity) can enter the market and compete with the incumbent firms.

In the retail segment competition is relatively strong. However, some problems may occur and are the outcome of the existing legal framework. More specifically, as a consequence of the existing legislation, hypermarkets, who can sell large quantities of gasoline with low cost (economies of scale), are not an active player in petrol retailing unlike in other European countries (e.g. United Kingdom and France).[5] As a result, gasoline retail prices before taxes and duties are systematically above the European average.

Another possible explanation for the price discrepancy is that petrol filling stations in Greece have due to their number—in their vast majority—low sales compared to other countries in the European Union. In order to cover their costs and not loose their customers they have to increase the retail margins, which are higher in Greece than in other European countries.

[4] With the oil law 3054/2002 that came into force since 2003, any marketer (refineries, oil companies, large industries) who wishes to import crude oil or final oil products (gasoline, diesel, heavy fuel oil, LPG, etc) must keep stocks (within the Greek territory) equivalent to 90 days of the net imported quantity.

[5] We must mention that in United Kingdom, supermarkets have grown continuously and significantly over the last years, whereas their volumes have grown at the expense of the traditional road site filling stations (OFT 1998).

3 Empirical methodology

Following the specification of Bettendorf et al. (2003), Galeotti et al. (2003), Kaufmann and Laskowski (2005), and Reilly and Witt (1998), various unrestricted error-correction models are used to link the relevant variables. In order to investigate the adjustment path in the different relevant gasoline markets (wholesale, retail market), we estimate two distinct asymmetric error-correction models that account for the wholesale and retail market, respectively. By taking into account, the previous considerations, the basic (long-run) relationships are the following:

$$\mathrm{SPG}_t = \beta_0 + \beta_1 \mathrm{CR}_t + \beta a_2 \mathrm{EXR}_t + \varepsilon_t \tag{1}$$

$$\mathrm{NRPG}_t = \beta_0 + \beta_1 \mathrm{SPG}_t + \varepsilon_t \tag{2}$$

The above equations represent the long-run relationships in the wholesale (Eq. 1) and retail market, respectively (Eq. 2).[6] The interpretation of the relevant variables comes as follows: SPG_t is the gasoline spot price at time t, NRPG_t is the retail price of unleaded gasoline net of taxes (excise tax and VAT) and duties at time t, CR_t is the price of crude oil, EXR_t is the exchange rate between U.S. dollar and national currency (drachmas), while finally ε_t stands for the disturbance term.

All prices are in their natural logarithms and expressed in drachmas per litre. The reason for using nominal exchange rate in the wholesale model is related with the fact that exchange rate may be a relevant source of asymmetry in non-US countries (Bacon 1991; Galeotti et al. 2003). More specifically, as stated by Galeotti et al. (2003), since crude oil is paid for in dollars whereas gasoline sells for different sums of national currencies, the exchange rate plays a significant, possibly asymmetric role.

The sample spans the period from January 1988 to June 2006 using an updated monthly dataset which consists of 222 observations to carry out a thorough investigation of gasoline market in Greece. We have chosen this extended dataset (from 1988 until the most recent months) for at least two reasons. Firstly, we want to capture the effect of deregulation on the oil market in Greece (1993 onwards) and try to link these results with the level of competition in the gasoline market. Secondly, since there was a legal change in the stockholding obligation in Greece (2003), it is interesting to check how the changes in inventory regulation effect the adjustment of gasoline prices to changes in the oil price.[7]

Energy prices (gasoline spot prices and crude oil prices) are taken from: (a) International Energy Agency (IEA) and especially from various issues of "Energy Prices and Taxes"[8] and (b) USA Department of Energy, Energy Information Administration

[6] Variables are in their natural logarithms.

[7] In 2001, the European Court of Justice (ECJ) condemned Greece for the existing strategic stockholding system that generated distortions in the competition of the oil industry (elimination of petroleum imports) and raised serious restrictions to the vertically integration of the market segments. As a result a new oil law (3054/2002) came into force in 2003.

[8] More precisely, we use the Brent crude oil prices as important marker crude and the spot gasoline prices as traded in Mediterranean, the major market for petroleum products in South-Eastern Europe. Spot price variable is a good measure of input price (wholesale) for retailers in Greece since both the refiners and

(EIA). However, pre-tax unleaded gasoline retail price (NRPG) is obtained directly from the Oil Bulletin of the Directorate-General for Energy and Transport of the European Commission.[9] Data on the exchange rate between the national currency (drachma) and the US dollar are obtained from the International Financial Statistics (IFS) for the period January 1988–December 2001. In January 2002, the Euro replaced the national currency (drachma) in Greece, although they continued physically existing until March of 2002.[10]

The asymmetry in the transmission of changes in input prices to output prices can be accommodated within a dynamic model (Galeotti et al. 2003). In order to allow for possible price and exchange rate asymmetries, we construct the following ECM specifications:

$$\begin{aligned}\Delta(\mathrm{SPG}_t) = a_0 &+ \sum_{i=0}^{k} a_i^{+}\Delta\mathrm{CRP}_{t-i} + \sum_{i=0}^{l} a_i^{-}\Delta\mathrm{CRN}_{t-i} + \sum_{i=0}^{m} b_i^{+}\Delta\mathrm{EXRP}_{\mathrm{t-i}} \\ &+ \sum_{i=0}^{n} b_i^{-}\Delta\mathrm{EXRN}_{t-i} + \sum_{i=1}^{p} c_i\Delta\mathrm{SPG}_{t-i} + \lambda^{+}\mathrm{ECMP}_{t-1} \\ &+\lambda^{-}\mathrm{ECMN}_{t-1} + \varepsilon_t \end{aligned} \tag{3}$$

$$\begin{aligned}\Delta\,(\mathrm{NRPG}_t) = a_0 &+ \sum_{i=0}^{k} a_i^{+}\Delta\mathrm{SPGP}_{\mathrm{t-i}} + \sum_{i=0}^{l} a_i^{-}\Delta\mathrm{SPGN}_{t-i} + \sum_{i=1}^{p} c_i\Delta\mathrm{NRPG}_{t-i} \\ &+\lambda^{+}\mathrm{ECMP}_{t-1} + \lambda^{-}\mathrm{ECMN}_{t-1} + \varepsilon_t \end{aligned} \tag{4}$$

where Δ is the first difference operator. In the above asymmetric ECMs (wholesale and retail), changes in the input prices (crude oil and spot prices) and fluctuations in the exchange rate are split into positive and negative changes, respectively. In other words as suggested by Galeotti et al. (2003), short-run asymmetry is captured by similarly decomposing price and exchange rate changes into $\Delta x_t^{+} = x_t - x_{t-1} > 0$ and $\Delta x_t^{-} = x_t - x_{t-1} < 0$ for $x =$ CR, SPG, EXR. Hence, ΔCRP $=$ ΔCR if ΔCR > 0 and 0 otherwise. ΔSPGP $= \Delta$ SPG if ΔSPG > 0 and 0 otherwise and ΔEXRP $= \Delta$ EXR if ΔEXR > 0 and 0 otherwise. The opposite holds for ΔCRN, Δ SPGN and Δ EXRN. Finally ECMP and ECMN denote the one-period lagged deviation from the long-run equilibrium (Eqs. 1, 2) and account for asymmetry in the adjustment process. Similarly, ECMP $= \varepsilon_t > 0$ and 0 otherwise and ECMN $= \varepsilon_t < 0$ and 0 otherwise. The orders *k, l, m, n* represent the number of lagged terms for decreases

Footnote 8 continued
the oil companies (wholesalers) use the Platt's quotations as a basis point price mechanism in the market. Hence, the spot price in Mediterranean is an informative proxy for the wholesale gasoline price in Greece.

[9] The bulletin reports weekly the average Monday's pump price without taxes and duties in each member state of the European Union.

[10] In December 2000, the drachma/euro exchange rate was definitely fixed at 340.75 drachmas. Taking into account this fixed exchange rate and that of Euro/dollar provided by the European Central Bank we calculate the exchange rate drachma/dollar on each month for the period January 2002–June 2006 by using the following formulation: drachma/dollar = 340.75 × euro/dollar.

and increases in the explanatory variables, respectively, and are chosen by using the Akaike Information Criterion (AIC) so as to make ε_t white noise.

For the investigation of the order of integration, we have applied a series of diagnostic tests both in levels and first differences of the variables (Augmented Dickey–Fuller, Phillips–Perron and KPSS tests). The results of the above tests are presented in Table 3. Applying the relevant tests, we observe that the null hypothesis of a unit root cannot be rejected at 5% critical value for all the relevant variables. In other words, all the series are non-stationary in levels. However, they are integrated of order one, or I(1) and do not include deterministic terms (trend and intercept).[11]

4 Empirical results

4.1 Long-run estimates

The next step is to examine if there is a cointegrated relationship between the non-stationary variables of the models. For this purpose, we applied both the (augmented) Dickey–Fuller test and the cointegrated Durbin Watson test (CRDW). From the empirical results (see Table 4), we found that at the 5% level of significance the disturbance term on each equation (wholesale and retail) is stationary or I(0). This means that, according to the Granger representation theorem there is one cointegrating vector which corresponds to long-run equilibrium between the non-stationary variables of each model (Engle and Granger 1987). OLS estimation of long-run relationships yields super consistent estimates of long-run responses of output prices to changes in input prices (Eqs. 1, 2) and exchange rates (Eq. 1).

The estimation period for this study covers the somewhat volatile time of significant oil price increases especially during the period 2003–2006. Hence, it is crucial to check the cointegration relationships for the existence of structural breaks. For this purpose we apply the Quandt–Andrews breakpoint test in order to capture possible changes in the output prices (Stock and Watson 2003). The results indicate the existence of a structural break in wholesale and retail prices in the long-run (Tables 5, 6). This means that in the long-run the pattern of gasoline output prices in Greece does not remain unchanged during the estimated period.

We now turn to the estimates of the long-run coefficients (standard errors are in parentheses)

$$\begin{aligned} \text{SPG} &= \underset{(0.15)}{0.34} + \underset{(0.01)}{0.95}\text{CR} + \underset{(0.21)}{0.56}\text{EXR} + \varepsilon \qquad (5) \\ \text{NRPG} &= \underset{(0.06)}{1.78} + \underset{(0.01)}{0.66}\text{SPG} + \varepsilon \qquad (6) \end{aligned}$$

In the wholesale specification (Eq. 5), the estimated coefficient on CR is significantly different from zero at the 5% significance level. The magnitude of the relevant

[11] It has to be mentioned that there is a general agreement in the literature that gasoline and oil prices are integrated of order one.

Table 3 Unit root testing

Variables	ADF						P–P		KPSS		Order of integration
	Lags	τ_t	Φ_3	τ_μ	Φ_1	τ	τ_t	τ_μ	n_t	n_μ	
Levels											
CR	0	−2.22	2.46	−0.31	2.33	1.46	−2.33 (3)	−0.38 (1)	0.27* (11)	1.65** (11)	I
SPG	0	−2.13	5.42	−0.75	3.41	1.48	−2.39 (3)	−0.41 (0)	0.29* (11)	1.63** (11)	I
NRPG	1	−3.25	6.10	−1.41	2.45	1.11	−2.83 (5)	−1.77 (15)	0.08 (10)	1.87** (11)	I
EXR	0	−3.37	5.75	−0.94	0.44	1.19	−3.99* (0)	−1.18 (9)	0.13 (10)	1.87** (11)	I
First differences											
Δ(CR)	0	−14.41**	–	–	–	–	−10.78** (0)	−10.79** (0)	0.04 (8)	0.12 (8)	I
Δ(SPG)	0	−13.58**	–	–	–	–	−8.75** (2)	−8.77** (2)	0.05 (8)	0.10 (7)	I
Δ(NRPG)	1	−15.30**	–	–	–	–	−17.14** (21)	−17.20** (21)	0.08 (18)	0.10 (17)	I
Δ(EXR)	0	−16.50**	–	–	-	–	−16.73** (7)	−16.75** (7)	0.02 (9)	0.04 (9)	I

The relevant tests are derived from the OLS estimation of the following autoregression for the variable involved: $\Delta Y_t = \delta + \beta \Upsilon_{t-1} + \gamma t + \sum \alpha_i^* \Delta Y_{t-i} + u_t$
τ_μ is the t statistic for testing the significance of β when a time trend is not included in the above equation, and τ_τ is the t statistic for testing the significance of β when a time trend is included in the above equation. The calculated statistics are those reported in Dickey and Fuller (1981). The critical values at 5 and 1% for $N = 50$ are given in Dickey and Fuller (1981). The lag length structure of α_i of the dependent variable y_t is determined using a recursive procedure in the light of a Lagrange multiplier LM autocorrelation test for orders up to 4 which is asymptotically distributed as chi-squared distribution and the value of t statistic of the coefficient associated with the last lag in the estimated autoregression. The critical values for the Phillips Perron unit root tests are obtained from Dickey and Fuller (1981). The number in parenthesis denotes the lags using the Newey–West bandwidth. n_μ and n_τ are the KPSS statistics for testing the null hypothesis that the series are I(0) when the residuals are computed from a regression equation with only an intercept and intercept and time trend, respectively. The critical values are given in Kwiatkowski et al. (1992)
Φ_1 and Φ_3 denote the non-standard F statistics reported in Dickey and Fuller (1981) that are used to test the joint hypothesis $H_0 = \delta = \beta = 0$ (absent of intercept) and $H_0 = \gamma = \beta = 0$ (absent of trend), respectively
** Significance at 1% level
* Significance at 5% level

Table 4 Tests for co-integration

Variables	ADF test	CRDW
U_{spg}	−7.70**	1.83**
U_{nrpg}	−3.32*	1.21**

U_{spg} and U_{nrpg} denote the error correction terms of spot and retail prices in the wholesale and retail equation, respectively. The t values reject the null hypothesis of no co-integration, indicating that the residuals are I(0). The critical values for the ADF test are obtained by Manning (1991)

** Significance at the 1% level

* Significance at the 5% level

Table 5 Recursive estimates for the gasoline spot prices (1988:01–2006:6)

Statistic	Value	Prob.
Maximum LR F statistic (1993M07)	19.01908	0.0048
Maximum Wald F statistic (1993M07)	19.01908	0.0048
Exp LR F statistic	7.470198	0.0035
Exp Wald F statistic	7.470198	0.0035
Ave LR F statistic	11.76588	0.0012
Ave Wald F statistic	11.76588	0.0012

Quandt–Andrews unknown breakpoint test
Null hypothesis: No breakpoints within trimmed data
Varying regressors: All equation variables
Equation sample: 1988M01 2006M06
Test sample: 1991M10 2002M09
Number of breaks compared: 132

Table 6 Recursive estimates for the gasoline retail prices (1988:01–2006:6)

Statistic	Value	Prob.
Maximum LR F statistic (1998M06)	138.5418	0.0000
Maximum Wald F statistic (1998M06)	138.5418	0.0000
Exp LR F statistic	65.86920	0.0000
Exp Wald F statistic	65.86920	0.0000
Ave LR F statistic	104.1999	1.0000
Ave Wald F statistic	104.1999	1.0000

Quandt–Andrews unknown breakpoint test
Null hypothesis: No breakpoints within trimmed data
Varying regressors: All equation variables
Equation sample: 1988M01 2006M06
Test sample: 1991M10 2002M09
Number of breaks compared: 132

coefficient means that a 1% increase of crude oil will lead to an increase of spot price of gasoline by 0.95%. In other words in the long run, a change in the crude oil price is fully passed to the wholesale price of gasoline.[12] This implies that the

[12] This finding is in alignment with other studies such as Contin et al. (2006).

margin is independent of crude oil price. Fluctuations in the exchange rate do play a significant role in the wholesale price formation. The relevant coefficient is positively related to the spot price of gasoline and its magnitude equals 0.56. In other words, an increase in the exchange rate (devaluation of drachma against the US dollar) will tend to increase the spot price of gasoline whereas the reverse holds in case of a decrease in the exchange rate (revaluation of drachma against the US dollar).

In the retail specification (Eq. 6), it is evident that all the coefficients are statistically significant and have the anticipated signs. More specifically, the price effect (SPG) on the net retail price of gasoline is positive and quite substantial in magnitude, with the relevant coefficient bellow unity (0.66). This means that a 1% increase (decrease) of gasoline spot price will lead to an increase (decrease) of the retail price—before taxes and duties—of gasoline by 0.66%. Similarly to the wholesale specification, a change in the gasoline spot price is fully passed through to the net retail price. The relatively smaller pass-through price mechanism is due to the fact that as we are moving down the oil supply chain, the price of upstream oil becomes a smaller portion of the cost of the price of oil in the next stage (wholesale). Therefore, a change in the upstream price of oil would generate a smaller price increase downstream (0.66%). Notice also that the coefficient on SPG represents the combined effect of a change in the world price of gasoline on the cost and on the mark up (Bettendorf et al. 2003).

4.2 Short-run estimates and asymmetries

4.2.1 Error-correction model estimates

In Table **7**, are shown the results from the estimation of the two ECM's referring to the wholesale (first column) and retail level of gasoline (second column). Each coefficient of the explanatory variables denotes the short-run response to the output prices (spot and retail prices). In order to select the appropriate number of lags in the two ECM's, we try to minimise the AIC.

More specifically, the dynamic function referring to the Greek wholesale gasoline market (first stage) appears to be well behaved to the diagnostic tests including the serial correlation (LM test), the autoregressive conditional heteroskedasticity test (ARCH test) and the White test for heteroskedasticity. In order to test whether the short-run regression is stable throughout the sample, we used recursive OLS techniques having pre-described above (see long-run estimates). All tests do not reject the null hypothesis of no split in the data. In other words, the estimated statistics support the structural stability of the estimated regression for the examined period used in the empirical analysis.

In the relevant table, the coefficients of the variables ECMP and ECMN indicate asymmetric adjustment speeds, which is a measure of long-run asymmetry. In other words as mentioned by Galeotti et al. (2003) the positive and negative ECM coefficients are associated with adjustment to the long-run equilibrium level of price from above and from bellow. In contrast to, the coefficients of all other variables account for short-run or transitory asymmetry.

Table 7 Estimation results of the ECMs

Variables	Δ (SPG)[a]	Δ(NRPG)[a]	Δ(SPG)[b]	Δ(SPG)[c]	Δ(SPG)[d]	Δ(SPG)[e]	Δ(SPG)[f]
C	0.01 (1.17)	−0.002 (−0.28)	0.03 (1.32)	0.004 (0.40)	0.007 (0.73)	−0.001 (−0.14)	0.04 (1.27)
	−0.006 (−0.68)	−0.017 (−1.28)	0.006 (0.30)	−0.010 (0.37)	−0.016 (−1.52)***	−0.02 (0.045)	0.03 (1.03)
$ECMP_{t-1}$	−0.38 (−4.73)**	−0.65(−3.21)**	−0.29 (−2.03)*	−0.45(−4.23)**	−0.35 (−3.85)**	−0.44 (−3.28)**	−0.56 (−3.14)**
	−0.21 (−2.38)*	0.09 (1.54)***	−0.14 (−0.88)	−0.26 (−2.26)*	−0.17 (−1.79)*	−0.21 (−1.61)***	−0.42 (−1.79)***
$ECMN_{t-1}$	−0.35 (−4.25)**	−0.58 (−2.98)**	0.09 (0.76)	−0.08 (−0.95)	0.02 (0.28)	−0.03 (−0.17)	−0.00 (−0.003)
	−0.43 (−4.19)*	−0.004 (−0.04)	−0.53 (−2.37)*	−0.40 (−3.36)**	−0.45 (−4.35)**	−0.45 (−3.73)**	−0.51 (−1.19)
ΔCRP_t	0.81 (7.48)**	–	0.63 (3.98)**	0.86 (7.95)**	0.73 (7.60)**	0.80 (6.15)**	1.03 (3.81)**
	0.70 (8.52)*		0.62 (4.36)**	0.78 (7.11)**	0.69 (8.03)**	0.74 (6.37)**	0.83 (2.83)*
ΔCRN_t	0.77 (8.61)**	–	0.84 (3.89)**	0.78 (5.28)**	0.82 (7.08)**	0.81 (5.98)**	0.74 (2.21)**
	0.78 (7.71)*		0.84 (3.94)**	0.74 (6.33)**	0.77 (7.41)**	0.74 (6.16)**	0.70 (2.13)*
$\Delta SPGP_t$	–	0.33 (4.37)**	–	–	–	–	–
		0.32 (2.90)**					
$\Delta SPGN_t$	–	0.27 (3.27)**	–	–	–	–	–
		0.46 (4.22)**					
$\Delta SPGP_{t-1}$	–	0.23 (2.90)**	–	–	–	–	–
		0.53 (5.64)**					
$\Delta SPGN_{t-1}$	–	0.38 (4.21)**	–	–	–	–	–
		0.29 (2.91)**					
ΔEXP_t	0.44 (1.81)*	–	0.32 (0.64)	0.36 (1.05)	0.71 (2.06)*	0.88 (1.87)*	−1.08 (−1.33)
	0.45 (1.54)***		0.27 (0.51)	0.35 (0.94)	0.72 (2.31)*	0.88 (2.08)*	−0.98 (−1.18)
ΔEXN_t	0.03 (0.11)	–	0.51 (0.43)	−0.01 (−0.08)	−0.04 (−0.13)	−0.17 (−0.47)	0.82 (0.66)
	−0.43 (−4.19)**		0.81 (0.87)	0.05 (0.15)	0.06 (0.21)	−0.08 (−0.24)	1.03 (0.83)

Table 7 continued

Variables	Δ (SPG)[a]	Δ(NRPG)[a]	Δ(SPG)[b]	Δ(SPG)[c]	Δ(SPG)[d]	Δ(SPG)[e]	Δ(SPG)[f]
ΔSPG_{t-1}	–	–	–	–	–	–	–
$\Delta NRPG_{t-1}$	–	−0.16(−2.58)*	–	–	–	–	–
		*−0.39 (−4.11)***					
Diagnostics							
Adjusted R^2	0.53	0.67	0.40	0.56	0.52	0.57	0.52
Durbin–Watson	2.13	2.03	1.90	2.22	2.10	2.25	2.11
F statistic	42.17 [0.00]**	20.05 [0.00]**	7.50 [0.00]**	35.60 [0.00]**	33.98 [0.00]**	27.34 [0.00]**	8.66 [0.00]**
LM test	1.34 [0.24]	1.41 [0.23]	0.069 [0.79]	1.99 [0.36]	0.74 [0.38]	2.48 [0.11]	0.32 [0.57]
LM (12)	3.44 [0.01]	4.16 [0.00]	0.66 [0.77]	2.02 [0.15]	1.14 [0.13]	3.24 [0.00]	0.33 [0.97]
White test	0.77 [0.76]	1.12 [0.30]	0.49 [0.96]	0.90 [0.59]	0.90 [0.60]	0.88 [0.62]	0.91 [0.58]
ARCH test	1.20 [0.27]	1.52 [0.68]	1.16 [0.28]	0.52 [0.47]	0.63 [0.42]	0.01 [0.99]	0.49 [0.48]
LMARCH (12)	0.97 [0.47]	3.38 [0.00]	0.67 [0.76]	0.63 [0.80]	1.00 [0.44]	0.47 [0.92]	0.72 [0.71]

The coefficients in italics are estimated using dynamic ordinary least squares (DOLS). The numbers in parentheses and in the square brackets are t and p values, respectively. C denotes the constant term. LM (12) and LMARCH (12) are Langrance multiplier tests for 12th order (1 year) autocorrelation and fifth order autoregressive conditional heteroskedasticity (ARCH), respectively

***, **, * Significance at 0.10, 0.01, and 0.05 respectively.

[a] Sample period 1988:01–2006:06 (whole period), [b] sample period 1988:01–1992:12 (regulated period), [c] sample period 1993:01–2006:06 (deregulated period), [d] sample period 1988:01– 2002:12 (period prior to the new stockholding regime), [e] sample period 1993:01–2002:12 (deregulated period with old stockholding regime), [f] sample period 2003:01–2006:06 (deregulated period with new stockholding regime)

From the empirical results and the subsequent statistical tests (see Sect. 4.2.3) it is obvious that positive coefficients are generally larger, in absolute value, than their negative counterparts for both in the long-run and short-run responses. This finding which is also evident in other empirical studies (Grosso and Manera 2007; Contin et al. 2006) reflects the consumers' perception of the actual effects of oil price variations on gasoline price changes at least in the short-run. This means that the effects of upstream price increases are larger than those of price decreases.

Table 5 also reports the transmission of shocks in exchange rates to output prices. On average over the estimation period, spot prices of gasoline register a well determined response to increases (or devaluations) in the drachma dollar exchange rate. This means that in the wholesale level, only positive changes appear to be significant. Our point estimate suggests that a 10% increase (or devaluation) in the drachma dollar exchange rate, rendering imported crude oil more expensive in terms of drachma, raises spot prices by ∼4%. This evidence suggests that refineries are generally reluctant to transfer to consumers those price reductions which originate from favourable movements in exchange rates (Grosso and Manera 2007).

Finally, the estimated autoregressive coefficients (positive and negative variations), which enter the model when the lag-length is equal to or larger than one have positive signs but fail to be statistically significant. Hence, they are not presented in the relevant table.

We now turn our discussion into the examination of point estimates in the retail level specification (column 2 in Table 5). In general terms, the dynamic equation fits to the data quite well, with high adjusted R^2 (0.67). The statistical tests reject the presence of autocorrelation of first or higher order and heteroskedasticity as well as autoregressive autocorrelation (ARCH effects). Finally according to the relevant statistics, no sign of structural instability has been detected.

From the empirical results, we see that positive short-run price effect is larger than its negative counterpart. This means that retail gasoline prices in Greece seem to react more to price increases and to negative gaps to the equilibrium than to price decreases and positive disequilibrium. This finding is also evident in other European countries as well. From the magnitude of the relevant estimates, we see that a 10% short-run increase in spot price of gasoline (wholesale price) will increase the retail price of gasoline by about 3.3%. This outcome is intuitively valid, since crude oil, refining costs and profit account for roughly 30% of retail costs, while taxes (excise taxes and VAT) and wholesale margin account for another 70%. Next in column 2, we study where the responsiveness of price is symmetric in decreases and increases of the spot price of gasoline. A rise in spot price of gasoline (SPG) of one unit induces a contemporaneous retail price increase of about 0.33, whereas a fall in SPG of one unit, results in a contemporaneous price effect of 0.27. Taken together this means that the price responded more rapidly to cost increases than to decreases. However, from the empirical interpretation, we conclude that a proportion of increases in SPG passed through in the same period (month) as they occur, whereas a small part of increases in SPG passed through in the previous month (point estimate of 0.23). Similarly, long-run price adjustments to decreases in SPG are distributed over 2 months (pass through of 0.27 in the same month and of 0.38 in the previous month). From the above analysis, it is evident that the accumulated pass-through in the retail price of gasoline (NRPG) is rather than symmetric.

If we try to compare the two-level analysis, some interesting remarks emerge. First, the magnitude of short-run coefficients is in the most cases larger in the wholesale than in the retail level. Second, the adjustment towards the equilibrium level is more gradual in the retail level revealing the differences between the wholesale and retail market. Furthermore, both the wholesalers and retailers tend to react more to price increases than price decreases. However, from the relevant magnitude of the price coefficients in the wholesale and the retail equations, we assume that retailers do not immediately transfer onto final prices (pump prices) all the adjustments in the wholesale prices. Instead changes are distributed over time (Grosso and Manera 2007). In other words, wholesale price increases and decreases affect retail prices for 3 months, whereas crude oil price variations (increases and decreases) affect the wholesale gasoline price for only 2 months (the initial month plus a lagged month).

The comparison of results from 1988–1992, which correspond to the period of regulation and 1993–2006, which correspond to the period of deregulation, is very interesting for understanding asymmetry and the role of government regulation. Besides, by capturing the effect of regulation on gasoline prices we are able to relate the results for 1988–1992 and 1993–2006 periods to the level of competition. This may provide a link between the role of competition in the oil market and the level of asymmetry (rockets and feathers hypothesis.[13])

From the empirical results, of the first ("regulated") period (1988:01–1992:12), we can see that only positive changes of the error correction term affect significantly the level of adjustment to long-run equilibrium (speed of adjustment equal to -0.29). This means that if the spot price of gasoline is 10% above its long-run equilibrium price, given the current crude price, the percentage change difference over a period of 1 month will be $0.10 \times (-0.29) = -0.029 = 2.9\%$ ceteris paribus. In other words, in the case, we are off the long-run equilibrium, the spot gasoline price will reach equilibrium in a 3 months period. The coefficients for the short-run crude oil positive and negative variations are statistically significant and equal to 0.63 and 0.84, respectively. Note also that exchange rate does not affect the estimated equation since the coefficients are not statistically significant.

The results vary significantly if we estimate the short-run spot price equation for the period after the regulation (1993:01–2006:06). More specifically, the speed of adjustment concerning the positive variations of the long-run equilibrium is larger in absolute value and equal to -0.45. This means that after the deregulation of the oil market, departures from the long-run equilibrium do not appear so "permanent" compared to the period prior to the opening of the market. Therefore, wholesale prices of gasoline tend to gradually restore equilibrium after the existence of a price shock (i.e. abrupt increase in the crude oil price). The coefficient of the short-run crude oil positive variations is larger in value that its negative counterpart (0.86 compared to 0.78). However, as in the previous case, exchange rate does not affect the estimated equation since the coefficients are not statistically significant

[13] Rockets and feathers is a term used to describe price behaviour where it is sudden increase but decreases at a much slower pace.

As stated in the previous analysis, there was a change in regulation of inventory behaviour in Greece in 2003. Hence, it is crucial to assess how the changes in the compulsory stock obligation affect the adjustment (e.g. speed of response and the long-run value) of gasoline prices to changes in oil price. In order to perform such analysis, we estimate the wholesale equation (Eq. 1) by splitting the sample size into three distinct sub-periods.

According to our results, in the first period (1988:01–2002:12), that covers the years prior to the implementation of the new compulsory stockholding obligation (regulated and unregulated period) that came into force in 2003, only positive changes of the error correction term affect significantly the level of adjustment to long-run equilibrium. More specifically, the speed of adjustment to the long-run equilibrium is estimated to -0.35, which has the following interpretation. If the spot price of gasoline is 10% above its long-run equilibrium price, given the current crude price, the percentage change difference over a period of 1 month will be $0.10 \times (-0.35) = -0.035 = 3.5\%$ ceteris paribus.

If we estimate the model for the unregulated period with the old stockholding regime (1993:01–2002:12) some interesting findings emerge. Firstly, we see that as in the previous period only positive changes of the error correction term affect significantly the level of adjustment to long-run equilibrium. The speed of adjustment to the long-run equilibrium is estimated to -0.44. This means that if the spot price of gasoline is 10% above its long-run equilibrium price, given the current crude price, 4.4% of the difference between the equilibrium price and the current price will be eliminated in the next month ceteris paribus. In addition, the coefficients for the short-run crude oil positive and negative variations are statistically significant and equal to 0.80 and 0.81 respectively. It is interesting to highlight that within this period, negative short-run price coefficient is slightly larger than its positive counterpart, while only positive changes in the exchange rate play a significant role in the short-run variations of spot gasoline price.

Lastly, if we estimate the wholesale model for the third period (2003:1–2006:6), that covers the years after the deregulation with the new stockholding regime, we see that the adjustment to the long-run equilibrium is more gradual since the relevant coefficient is estimated to -0.56. The coefficients for the short-run crude oil positive and negative variations are statistically significant and equal to 1.03 and 0.74, respectively. It is interesting to highlight that in the latter period, positive short-run price coefficient is larger than its negative counterpart while the reverse holds for the former period.

To sum up, the above results do not change dramatically if we estimate the short-run relations (Eqs. 3, 4) by using dynamic ordinary least squares (DOLS), as described in Stock and Watson (1993).

4.2.2 *Impulse response functions*

Although the above analysis shows that there are short run relationships between the variables of each model, it does not reveal the direction of their causal relationship. An alternative way to obtain the information regarding the relationships among the variables of the two relevant models is through the estimation of the impulse response functions (IRF's). The IRF's can be interpreted as the response of price (spot and retial

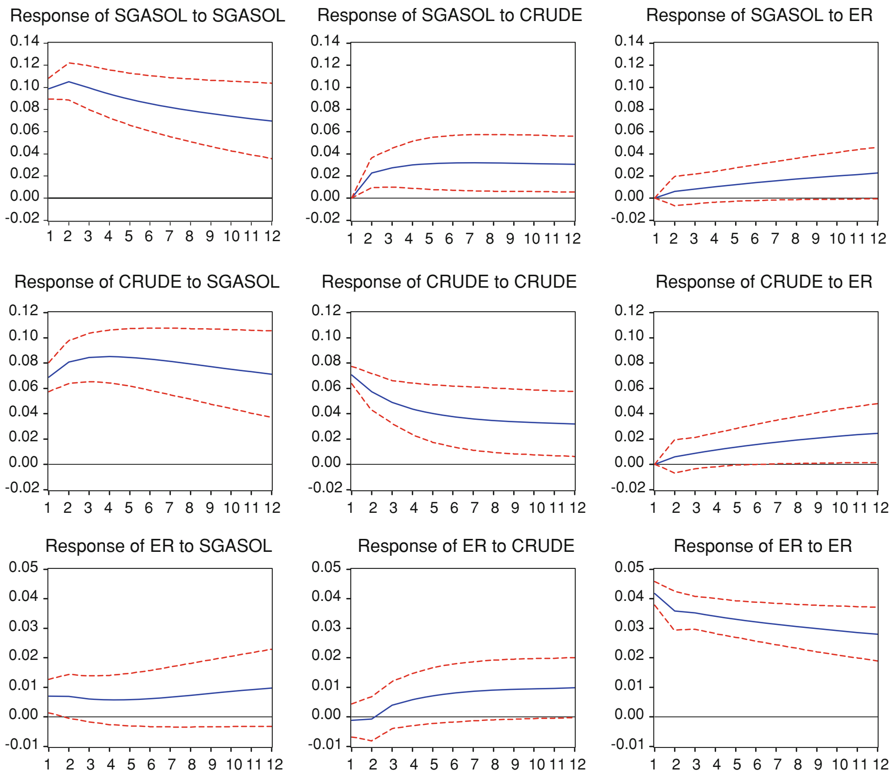

Fig. 3 Impulse response functions for spot gasoline price. *Source*: Author's calculations

price of gasoline) to a cost shock that pushes the system temporarily out of its long-run equilibrium and illustrate the speed of gasoline price adjustment to the long-run values estimated using Eqs. 1 and 2.

The IRF's derived from the unrestricted VAR for spot price of gasoline are presented in Fig. 3. From the first row of the diagram, it is evident that the effect of one standard deviation shock of the price of crude oil (CRUDE) on spot price of gasoline (SGASOL) is positive and significant for a period of 5 months. Subsequently, the confidence bounds become very wide, making the response of spot price of gasoline to oil shocks fluctuations insignificant. The peak response of spot price of gasoline to crude oil price innovations occurs 5 months after the initial shock, stabilizing thereafter. This means that an oil shock is rather than short-lived. This outcome reveals crucial information regarding the transmission of upstream shocks (increase of crude oil price) to downstream prices (wholesale and retail prices). As stated in Sect. 2.2, the duopoly that exists in the refining sector in Greece has an important implication for the wholesale market given the limited level of petroleum imports. The increasingly rate of response of spot price of gasoline to crude oil shocks and the stabilization after the first 5 months, gives an indication that a market power effect (running from the refiners to wholesalers) holds in the spot gasoline price changes.

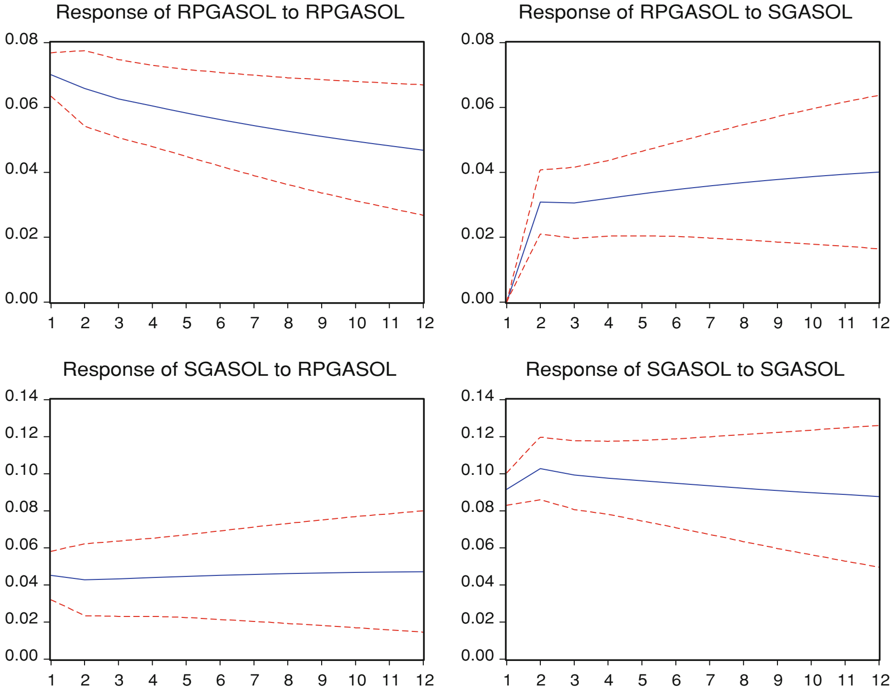

Fig. 4 Impulse response functions for retail gasoline price. *Source*: Author's calculations

Moreover, the response of spot price of gasoline to a one standard deviation shock of exchange rate (ER) is also found to be positive and statistical significant for the first 8 months, representing that a devaluation of drachma against the US dollar will tend to increase the spot price of gasoline whereas the opposite holds in case of a revaluation. The same pattern (positive relationship) follows the response of spot price of gasoline to a standard deviation shock of exchange rate. Lastly, the response of spot price of gasoline to its own innovations is found to be increasing for the first 2 months and decreasing and not statistically significant for the subsequent period.

The IRF's derived from the unrestricted VAR for retail price of gasoline are presented in Fig. 4. It is evident from the first row of the diagram, that the effect of one standard deviation shock of spot price of gasoline on retail price (RPGASOL) is positive and significant for almost a period of 3 months. Subsequently, the confidence bounds become very wide, making the response of retail price of gasoline to wholesale price fluctuations insignificant. It is crucial to mention that the positive relationship between the two variables has also been detected in the cointegration analysis. In addition, the response of spot price of gasoline to its retail price innovations is stable across the whole period (12 months). Lastly, the response of retail price of gasoline to its own innovations is positive with a decreasing rate during the simulated period.

4.2.3 Price and exchange rate asymmetries

Having estimated the short-run responses of the output prices to input variations, we focus on the gasoline price asymmetry hypothesis both in the wholesale and retail level. Table 8 reports the calculated Wald tests testing the asymmetry hypothesis in the wholesale and retail level. More specifically, rejection of the null hypothesis

Table 8 F tests of asymmetric responses

Null hypothesis (H_0)	$\lambda^+ = \lambda^-$ (symmetric adjustment speeds)	$\alpha^+ = \alpha^-$ (price asymmetry)	$b^+ = b^-$ (exchange rate asymmetry)	$\alpha^+ = \alpha^- = \beta^+ = \beta^- = 0$ (short-run asymmetry)
(1988:01–2006:06) 222 observations				
Wholesale level	12.15* [0.00]	0.079 [0.77]	0.57 [0.44]	2.49** [0.06]
	1.75 [0.18]	*0.23 [0.63]*	*0.37 [0.54]*	*250.94 [0.00]]*
Retail level	4.44* [0.03]	5.12* [0.00]	–	–
	0.46 [0.49]	0.012 [0.91]		
(1988:01–1992:12) 60 observations				
Wholesale level	3.56** [0.06]	0.41 [0.52]	0.01 [0.88]	0.29 [0.83]
	1.50 [0.22]	*0.59 [0.44]*	*0.18 [0.66]*	*55.98 [0.00]*
Retail level	3.58* [0.02]	2.39** [0.06]	–	–
	0.32 [0.57]	*1.97 [0.16]*		
(1993:01–2006:06) 162 observations				
Wholesale level	1.46 [0.22]	0.15 [0.69]	0.40 [0.52]	2.63** [0.05]
	0.51 [0.47]	*0.04 [0.83]*	*0.28 [0.59]*	*185.31 [0.00]*
Retail level	1.08 [0.38]	3.68** [0.05]	–	–
	0.002 [0.96]	*1.83 [0.17]*		
(1988:01–2002:12) 180 observations				
Wholesale level	8.69* [0.00]	0.26 [0.60]	1.79 [0.18]	1.86*** [0.13]
	2.70 [0.10]	*0.31 [0.57]*	*1.69 [0.19]*	*224.81 [0.00]*
Retail level	7.06* [0.00]	2.06** [0.06]	–	–
	1.96 [0.16]	*0.26 [0.60]*		
(1993:01–2002:12) 120 observations				
Wholesale level	3.53*** [0.06]	0.0005 [0.98]	2.40 [0.12]	2.18*** [0.09]
	1.19 [0.27]	*0.0004 [0.98]*	*2.48 [0.11]*	*161.98 [0.00]*
Retail level	0.03 [0.86]	4.67** [0.03]	–	–
	0.68 [0.40]	*0.39 [0.52]*		
(2003:01–2006:06) 42 observations				
Wholesale level	6.44* [0.01]	0.29 [0.58]	1.23 [0.27]	1.98*** [0.13]
	0.025 [0.87]	*0.053 [0.81]*	*1.31 [0.25]*	*27.62 [0.00]*
Retail level	6.15* [0.01]	1.96*** [0.16]	–	–
	2.59 [0.10]	*2.15 [0.14]*		

The coefficients in italics are estimated using dynamic ordinary least squares (DOLS)

*,**, *** Significance at 0.01, 0.05, and 0.10, respectively. The numbers in square brackets are p values

$H_0 : \lambda^+ = \lambda^-$ implies asymmetric long-run adjustment, whereas short-run asymmetries (price and exchange rate) arise when at least one of the hypotheses $H_0 : \alpha^+ = \alpha^-$ or $b^+ = b^-$, is rejected. By using the relevant tests, we see that the hypothesis of symmetric adjustment speeds can be rejected at the wholesale and retail level as well. This means that we have found evidence of an asymmetric response of the rate of adjustment towards the long-run equilibrium. However, for the period after the deregulation (1993–2006), the null hypothesis $\lambda^+ = \lambda^-$ in the wholesale and retail level cannot be rejected ($F = 1.46$, p value=0.22 $F = 1.08$, p value=0.38, respectively). In other words, there is a symmetric response of the rate of adjustment toward the long-run equilibrium in all the segments of the gasoline market. Similar conclusion can be traced in the paper of Contin et al. (2006).

From the combined results of the above-mentioned Wald-tests, we reach the conclusion that there is a symmetric response of the output prices of gasoline in the wholesale level. This conclusion which can be found in other empirical studies as well (Godby et al. 2000; Galeotti et al. 2003; Contin et al. 2006) runs contrary to the common perception regarding the price asymmetries that emerge in the gasoline market. Similar results can be traced when testing for exchange rate asymmetry in the wholesale level. However, when we simultaneously test the equality of all short-run parameters of the same lags in the wholesale level the null hypothesis (equality hypothesis) is rejected in all sub-periods except for the period of regulation ($F = 0.29$, p value=0.83). Despite the fact that no sign of price asymmetry is detected in the wholesale level, we must mention that there is a tendency to over-reject the null hypothesis of symmetry due to the low power of standard F statistics (Galeotti et al. 2003). However, when we test for price asymmetries in the retail segment of the market, the null hypothesis is rejected for all the periods of estimation suggesting the existence of asymmetric retail price responses to changes in the spot (wholesale) price.

Although the OLS estimate of the cointegrating vector is superconsistent, it will contain a small-sample bias and the limiting distribution is non normal with a non-zero mean (Stock 1987). A bias in the estimate for the cointegrating vector will affect the cointegrating residual, which is an independent variable in the error correction model (Eqs. 3, 4). To test for the potential effect of this bias and the robustness of the econometric results, we estimate cointegrated relationships (Eqs. 1, 2) using DOLS.

We chose DOLS because the variables in Eqs. 1 and 2 contain a stochastic trend (Table 1). The number of lags and leads is chosen using the Bayesian information criterion (BIC). The coefficients estimated by DOLS represent the long-run cointegrating relation among variables. It is worth mentioning that DOLS increases the efficiency and reduces the small sample bias relative to the OLS estimator, while DOLS generates asymptotically efficient estimates of the regression coefficients for variables that cointegrate (Kaufmann and Laskowski 2005).

More specifically, when we use DOLS, we conclude that the bias in the OLS estimate of the cointegrating relation affects the tests of the symmetry restriction. The symmetry restriction cannot be rejected at the 5 or 10% level for any of the two oil segments (wholesale and retail).[14] Similar results can be depicted when testing for exchange rate asymmetry in the wholesale level whereas the null hypothesis cannot be rejected at any level of statistical significance. Lastly, when we simultaneously test the equality of all short-run parameters of the same lags in the wholesale level the null hypothesis (equality hypothesis) cannot be rejected in all sub-periods suggesting the existence of symmetric retail price responses to changes in the spot (wholesale) price. Based on the above analysis, we conclude that the bias in the OLS estimate for the cointegrating relations probably is responsible for the lack of an asymmetric price response.

Much of the recent literature is devoted not to simply testing for asymmetries but rather attempts to explain why these markets generate asymmetries. The most commonly used explanations include the exercise of market power by oil companies and the existence of consumers search costs. However, despite common belief and an explanation linking concentration to the asymmetry between variations in crude oil and gasoline prices, there does not appear to be much evidence of monopolisation in any stage of the Greek gasoline market (wholesale and retail segment).[15] As stated above, the market share claimed by the four largest oil companies in Greece in 2005 (58.4%), as well as a relatively low HHI of 1.086, indicates that gasoline distribution in the wholesale segment is competitive when viewed at the national level. The theory of market power also seems difficult to exist in the retail sector. More specifically, given the large number of retail gasoline stations (8.500 retailers) makes complete monopolisation unlikely. However, in rural areas and small towns, regional monopolies could exist and gasoline stations have often been cited as examples of monopolistic competition (Brown and Yucel 2000). In this case, the government could carefully monitor the evolution of prices in these areas and ensure that filling stations operators do not abuse their dominant position.

Except market power, consumer search costs are another possible explanation for the existence of asymmetric response of retail gasoline prices to changes in the wholesale price (see Borenstein et al. 1997; Borenstein 1991; Radchenko 2005; Peltzman 2000). According to the search cost theory, each filling station has a locational monopoly which is limited by consumer search. When wholesale prices rise, the owner of each station acts to increase profit margins and quickly passes the increase to final consumers. On the contrary, when prices fall each station temporarily boosts its profit margins by slowly passing the decrease on to consumers. Only after the consumers engage in a costly and time-consuming search to find the lowest prices are the filling stations operators forced to lower prices to a competitive level. According to this theory, volatile crude oil prices create a signal-extraction problem for consumers; it encourages consumers to search less thus making gasoline filling station operators less competitive (Radchenko 2005).

Finally, beyond market power and search costs, economists have offered numerous possible explanations for the asymmetric response of gasoline prices to movements in crude oil prices. Alternative explanations include markups that vary over

[14] All symmetry tests were evaluated against a χ^2 distribution with one degree of freedom.

[15] The reverse outcome holds for the refining stage, since there are only two refining companies (Hellenic Petroleum S.A and MOTOR OIL S.A.) in Greece and imports of petroleum products are still limited.

the business cycle, consumer response to changing prices, inventory management, accounting practices and refinery adjustment costs (Brown and Yucel 2000). Despite the crucial importance of the relevant topic to pursue policy objectives, no one—to the best of our knowledge—has performed formal econometric tests that would allow the testing of the various explanations for price asymmetry in Greece against the available data. Therefore as stated in the comprehensive survey of Brown and Yucel (2000), in the absence of such empirical tests, economic theory can be used as a guide to investigate the determinants of the price asymmetric responses of gasoline.

5 Conclusions and policy implications

The relevant empirical study uses an updated monthly dataset (1988–2006) to carry out a detailed investigation of gasoline market in Greece. For this purpose, we distinguish the process of transmission of oil price shocks to gasoline prices into two parts corresponding to a first wholesale level and then to a second distribution stage (retail level). By doing so, we are able to assess possible asymmetries at either one or both levels. In the specific study, we used two asymmetric ECMs at each market segment in order to distinguish between asymmetries arising from short-lived deviations in input prices (crude oil and spot prices) and asymmetries concerning the speed at which the gasoline price reverts to its long-run (equilibrium) level. Moreover, we allow for an explicit role of the exchange rate and a detailed competition analysis to which rather scant attention has been paid by the earlier studies.

On average over the estimation period, spot prices of gasoline register a well determined response to increases (or devaluations) in the drachma dollar exchange rate. This evidence suggests that refineries are generally reluctant to transfer to consumers those price reductions which originate from favourable movements in exchange rates. Furthermore, from the relevant findings we conclude that after the deregulation of the oil market, departures from the long-run equilibrium do not appear so "permanent" compared to the period prior to the opening of the market. Therefore, wholesale prices of gasoline tend to gradually restore equilibrium after the existence of a price shock. This might be the outcome of the gradually opening of the oil market and the appearance of competition which until 1992 was regulated by the government. However, deregulation and the stockholding regulations did not automatically lead to symmetrical price movements of the oil industry. This is mainly attributed to the existence of structural distortions in all of the three relevant markets of the oil industry that hamper the level of the effective competition.

When we divide the whole data set into two sub-samples (unregulated with old and new stockholding regime) some interesting findings for the scope and the impact of stockholding regulations emerge. More specifically, in the unregulated period prior to the implementation of the existing compulsory stock obligation (1993–2002) the adjustment to the long-run equilibrium is not as rapid as in the unregulated period with the new stockholding regime (2003–2006). The relevant coefficients have the anticipated signs (-0.44 and -0.56, respectively). Furthermore, in the period with the old inventory regulation mechanism the positive short-run price coefficient is lower than its negative counterpart while the reverse holds for the second period whereas the coefficient of positive crude oil price shocks is larger than unity. Lastly, only in the first period positive changes in the exchange rate do play a significant role in the short-run variations of spot gasoline price.

According to the results of the IRF, there is an increase over the subsequent period of the importance of crude oil price and exchange rate fluctuations to explain variations in the gasoline price, confirming the long-run relationship found to hold among them by the cointegration analysis. The peak response of spot price of gasoline to crude oil price innovations occurs 5 months after the initial shock, stabilizing thereafter. This means that an oil shock is rather than short-lived, leaving room for debate concerning a possible exercise of market power by the refineries to wholesale gasoline price changes. This might be the outcome of the rather unique market structure of the Greek oil sector compared to other (European) countries consisting of three distinct market segments (refineries, wholesalers and retailers) and the absence of vertical integration especially in the wholesale segment.

From the statistical inference (Wald tests) we reach the conclusion that there is a symmetric response of the spot prices of gasoline towards the adjustment to the short-run responses of crude oil. The same finding can be traced when testing for asymmetric responses of spot price to changes in the exchange rate. However several reasons related to the market structure, the frequency of the data and the related econometric methodology could partially explain the lack of asymmetry in the Greek gasoline market. In the retail segment of the gasoline market, the null hypothesis (symmetric response) is rejected for all the sub-periods confirming the existence of asymmetric retail price responses to changes in the spot (wholesale) price. However, when we use DOLS, we conclude that the symmetry restriction cannot be rejected for any of the two oil segments (wholesale and retail).

Except for the possible exercise of market power by the refineries, asymmetries in the gasoline market are likely to be the outcome of other market parameters. As such policies to suppress asymmetric price movements are not likely to have the anticipated results. The best policy in order to protect consumers from welfare loses concerns the implementation of regulatory and behavioural measures as well. First of all, the strengthening of the role of the wholesalers and the elimination of certain barriers to entry in the oil market could provide a suitable mechanism to enhance the level of petroleum imports in Greece. In this way, oil prices (gasoline, heating oil, light fuel oil) should not be driven by the refineries (Platt's quotation plus a markup). Oil imports instead should affect the price of petroleum products in Greece. Another suitable policy in order to prevent the market players from the imposition of exploitative practices (i.e. price fixing, abuse of dominant position) that hinder the level of competition in all of the three market segments is linked with a thorough investigation of mergers. Mergers in the oil sector that increase market concentration without creating economies of scale can have anticompetitive effects and increase the market power of the incumbents. In such cases where competition is hampered, the government should develop a closely monitoring of the market in order to prevent the marketers from concerted practices. In the retail level, the Greek government could enhance the level of competition by a further opening of the market to new entrants such as hypermarkets or big stores and by removing certain legal or technical barriers for the establishment of new filling stations. The industry structure in other European countries (United

Kingdom, France and Germany) consisting of vertically integrated companies and significant market players (hypermarkets) in the retail segment could be a useful tool to the Greek policy makers.

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